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DEPARTMENT OF THE INTERIOR

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ESSENTIALS IN DEVELOPING AND FINANCING A PROSPECT INTO A MINE

BY

CHARLES WILL WRIGHT

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DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

ESSENTIALS IN DEVELOPING AND FINANCING A PROSPECT INTO A MINE[1]

By Charles Will Wright[2]

FOREWORD

This paper will be of interest to those who are actually developing a mineral prospect or planning to do so, as well as to investors who are considering the problem of financing the development of the prospect, so that they may know what the risks are and what capital expenditures are necessary before a prospect may become a mine.

The term "prospect" used broadly, as it is in this paper, is defined as any property that has a mineral showing of sufficient interest to warrant development, irrespective of prior work. Such previous exploration, however, may be extensive and consist of several tunnels or adits connected by raises, or of shafts with several levels. There may also be a small mining and milling plant on the prospect which, because of the lack of capital for development or the lack of markets for the products, is now idle. Such prospects may warrant further capital investment for development work or for a mine plant to raise to the stage of profitable production.

The four essentials that go into the making of a mine are:

(1) A prospect with a persistent or continuous ore body favorable for the development of a sufficient tonnage of profitable ore and located within a reasonable distance from water supply and transportation facilities.

(2) Sufficient capital for development work and for the installation and operation of a mine and mill plant to make the property remunerative.

(3) A ready market for the product.

(4) Competent and efficient management.

All four are necessary for success, but the last is particularly important.

To develop a mine, it must first be financed through the prospect stage. The risk of capital investment is greatest during this stage, and failures often may be ascribed to the unwise use of the available capital rather than to lack of minable ore and to mining conditions. The advice and opinion of a competent mining engineer are essential in any mining venture but are of major importance in the development of a prospect. The chances of failure are reduced greatly by the application of sound financing on business principles and by placing a man in charge of the work who has had technical training and experience in mine management. The death rate among promising prospects is very high. Some engineers claim that less than 1 percent of all prospects develop into profitable mines. All prospects, however, do not remain dead, and due to the stimulus of higher metal prices or improvements in metallurgical processes often are revived; sometimes these eventually become mines.

Before starting to raise capital it is necessary to have a detailed report on the property prepared by a competent mining engineer. Unfortunately, this is done in exceptional

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1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U.S. Bureau of Mines Information Circular 6839."

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cases only. Such a report should contain topographic and geologic maps, plans, and sections of the mine workings; assay records of the ore exposures, stating how samples were taken; and estimates of the tonnage and grade of ore developed[3], the possible tonnage that may be developed by future exploration, and the cost of such development work. Information Circular 6748, Essentials for a Preliminary Report on a Small Lode-Gold Mine or Prospect, with Notes on Sampling, written by the author, was issued in October 1933. Its object was to aid the owner of a small gold mine or prospect in preparing a report on his property for the purpose of interesting capital, but its essential features apply equally to ores other than gold.

Owners of small mines or prospects should prepare several copies of such a report, with illustrations and maps bound together. Fortified with information based on the data in such a report, they may then solicit financial aid. The investors, however, must know how much capital expenditure is required and justified and for what purposes it is to be used; and they also should have an estimate of the probable returns on the investment and when these may be expected. To make such an estimate is not an easy task, even for an experienced engineer, because there are so many unknown factors that have to be evaluated.

The object of this paper is to give to investors and mine owners a clearer conception of the risks they will encounter in attempting to make a mine out of a prospect and to point out the importance of geological studies, development work, tonnage estimates, mill tests, and management, as well as the market outlet and value of the product. Its purpose is also to point out to owners of a prospect the investors' viewpoint and ways to minimize risks to both owners and investors. Specific financing plans, providing enough capital to prepare the property for remunerative production over a period of years, are also improtant for its ultimate success.

In mining, as well as in other commercial enterprises, failure to anticipate capital requirements fully before productive operations are begun frequently has resulted in financial disaster to the enterprise. Thorough investigation and estimates of the ultimate cost of developing and equipping a property to the productive stage are therefore important before any major expenditure is started.

IMPORTANCE OF GEOLOGICAL STUDIES

Geological studies are necessary for determining the probable extent of an ore deposit, and one should have a clear conception of ore-forming processes before he makes estimates of ore reserves[4], particularly as to the tonnage of probable[5] and possible[6] ore present. It is only when these natural processes are understood that assumptions may be made as to the continuity and uniformity of mineral content. From a miner's standpoint ore bodies may be grouped in four general classes:

(1) Vein or lode deposits, where the ore minerals occupy a fissure or series of fissures in the country rock.

(2) Massive sulphide or replacement deposits, where the ore occurs in segregated masses, usually in limestone or in the vicinity of intrusive rocks.

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3 Ore developed or blocked out is that accessible for measurement and sampling on at least 3 sides not over 150 feet apart in regular deposits. In irregular deposits the estimate is based more on an engineer's judgment than on mathematical calculations.

4 Ore reserves are the estimated tonnage of ore to be mined.

5 Probable ore includes those portions of the ore body that have been exposed on two sides, plus a small portion of the ore body beyond these sides.

6 Possible ore includes areas within an ore body exposed on one side where ore may be reasonably expected to occur.

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(3) Disseminated deposits, consisting of sulphide minerals scattered through masses of either intrusive or sedimentary rock .

(4) Bedded deposits.

Where prospects are in known mining districts a study of the neighboring mines should be made to obtain all available knowledge of the habits and occurrence of minable ore[7] in the vicinity, the size, shape, and persistence in depth of the ore shoots, and the possibility of faults and their effect on continuity of the ore.

The country rock in which the ore deposit occurs and the type of deposit as well, are important factors in determining the persistence of the ore body. Deposits in limestone and along contacts of intrusive rocks[8] with limestone and other sedimentary rocks usually are irregular in shape, and the individual ore masses often are limited in extent but sometimes are very large. Inferences drawn from outcrops as to the form and size of such contact metamorphic deposits[9] are unreliable, and predictions of extension much beyond exposed faces are unsafe. Exploration of such deposits should be confined to the borders of the intrusive rocks, except where a pronounced mineral zone extends outward from the intrusive masses.

Careful study of the occurrence of ore shoots[10] within a mineral zone or a vein or lode is also important in planning developments. Ore shoots may be distinguished by the presence of certain minerals or their relationship to geological features. Some occur where cross-fractures intersect a mineral zone or vein, others where the vein itself is strongly fractured or where there are vugs or cavities in the vein. Anticlines or synclines[11] in sedimentary rocks[12] are often favorable points for deposition of ore, and the proximity of dikes may also be indicative.

Most nonferrous metalliferous deposits occur in districts of abundant igneous[13] intrusive rock , and the ore bodies often are found close to the contacts of the intrusive masses. In certain areas it has been observed that fingerlike extensions from large masses of intrusive rocks point to the places where the ore bodies occur. In other instances they occur where the intruded rocks form embayments in the line of contact.

The proximity of an ore body where limestone is the enclosing rock sometimes is indicated by dolomitization[14] of the limestone, a change that may extend a considerable distance from the ore body. Where shales or schists enclose the ore bodies there is often a silicification[15] of the wall rocks, and the rock near the ore bodies is of a lighter color or appears to have been bleached.

A trained geologist will observe numerous chemical and structural characteristics. From these observations, together with a carefully prepared geological map of the area where the ore bodies occur, interpretations may be made which are of utmost importance in planning

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7 Minable ore is ore which will yield a profit under normal conditions.

8 Intrusive rocks are those rock masses or dikes that have been pushed up into the bedded rock, such as granite and porphyry.

9 Contact metamorphic deposits are those that occur in the altered rock areas between the intrusive rock masses and bedded rocks.

10 Ore shoots are portions of a vein or ore body carrying high-grade or paying ore.

11 An anticline is an arch or fold of rock strata bulging upward, while a syncline is a U-shaped fold.

12 Sedimentary rocks are composed of material derived from the erosion or decay of other rocks.

13 Igneous rocks are those consolidated from a molten state; they include both volcanic and intrusive rocks.

14 Dolomitization is the change from limestone to dolomite caused by an impregnation of carbonate of magnesium into the limestone, forming a calcium magnesium carbonate.

15 Silicification is caused by the penetration of solutions carrying silica and depositing this silica in the rocks adjacent to the fissures in which ore may occur.

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the future development of an ore body. The new edition of Ore Deposits, by W. Lindgren,[16] presents clearly the value of geological studies, and The Principle of Economic Geology, by W. H. Emmons,[17] gives an excellent discussion of all kinds and types of ore bodies and their formation.

Certain types of ore deposits are more continuous than others. The vein and lode deposits are the most persistent, and predictions often can be made with some degree of certainty as to the continuity of ore between known points for deposits of this type. However, it is seldom safe to gage the size of a treatment plant by information based on estimated tonnages of possible ore in ore bodies which have been exposed on one side only or opened by a single tunnel or drift.[18]

Often the metal content of an ore deposit depends upon whether it has been subjected to secondary enrichment.[19] In northern glaciated regions primary ores usually extend to the surface, and oxidation with secondary enrichment is unimportant. In dry climates, where erosion has been less, time has allowed extensive decomposition of the ore bodies near the surface, and part of their metal content has been carried in solution and deposited at lower levels. As the extent of this secondary enrichment varies greatly with depth and as the metal content of the ore is not uniform, estimates of possible ore beyond known limits are highly speculative. It is therefore necessary to recognize secondary enrichment and to determine by exploration whether valuable ore may exist below the ore exposed and whether the enriched ore will be succeeded in depth by workable primary ore.[20]

Well-defined fissure veins that are exposed for a thousand feet or more along the surface would be expected to continue for several hundred feet in depth, under normal conditions, unless they are cut off by some structural feature in the enclosing rocks that is not apparent from the surface. Such structural terminations may be caused by a sudden pinching or closing of the fissure in which the vein occurs or by a fault displacing the ore body, beyond which its extension is uncertain.

Examples

(1) A deposit of copper ore in southeastern Alaska, which occurred on a mountain divide at the contact of a granite mass with limestone, was partly explored by trenches and short tunnels. Due to oxidation of the sulphide deposit, malachite, azurite, and limonite were formed, and these surface minerals were spread over a wide area, giving the appearance of a large deposit. Instead of sinking a shaft to determine the depth of the deposits a tunnel 2,000 feet long was driven to develop the deposit at a depth of 600 feet. Meanwhile an aerial ropeway, smelter, and wharf were built. No ore was disclosed by the tunnel, and later the deposit was bottomed by a shaft at less than a hundred feet below the surface. Had the shaft been sunk in the ore at the start or a tunnel driven 100 feet below the outcrop about a million dollars in useless expenditure would have been saved. Moreover, examination of the other copper deposits in this area would have shown that this type of ore body was limited in lateral and vertical extent and secondary enrichment confined to within a hundred feet of the surface.

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16 Lindgren, W., Ore Deposits, 4th ed.

17 Emmons, W. H., The Principles of Economic Geology: McGraw-Hill Book Co., New York, N.Y.

18 The term "tunnel" is used commonly instead of adit or drift, although if strictly interpreted a tunnel is an opening extending entirely through a hill, but in mining literature and among mining men a tunnel is a passageway into a hill.

19 Secondary enrichment of a vein or an ore body is an enrichment by material of later origin, usually derived from the oxidation of decomposed, overlying ore masses.

20 Primary ores are those first or originally formed in an ore deposit before alteration began.

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(2) A vein deposit of lead ore in sericite schist had been developed and mined over a length of 3,000 feet above the adit level. A shaft was sunk 200 feet, and at a depth of 100 feet a level was opened up for a length of 1,000 feet; this showed the vein to be wider and just as rich as on the upper level. Estimates were made of probable and possible ore down to and below the 200-foot level, and based on these estimates a new mill and power plant were built. The 200-foot level was started in ore, but a pinch in the vein, which extended the entire length of the vein between the 100- and 200-foot levels, was encountered a short distance from the shaft. Winzes were sunk below the 100-foot level at several points until the pinch was found. Exploration below the 200-foot level failed to disclose the extension of the vein below the pinch. Based upon the assumptions made and upon normal conditions for this type of deposit the capital expenditure would have been recovered, but the example shows that speculations on estimates of possible ore are hazardous.

IMPORTANCE OF GEOPHYSICAL PROSPECTING METHODS

Geophysics has been a valuable aid in many instances in exploration of mineral deposits. Both electrical resistivity methods and the magnetometer have been used extensively in tracing the extension of ore veins and faults and in determining subterranean geological features that affect the occurrence of minerals. It is, however, no easy matter to interpret the results of the field survey , and to do so usually requires a thorough knowledge of geology. At most, these surveys can show only certain anomalies within an area that will correspond to those caused by an ore body, a fault, or some geological characteristic in a known area and thus indicate a favorable place for exploration. It is therefore most important to use more than one geophysical method within an area, so that the geophysicist may be prepared to check the interpretation of the data and to make detailed geological studies before he begins costly underground explorations. Geophysical methods also are used to check geological deductions and supplement them, and in any extensive mine development the use of these methods should be considered.

IMPORTANCE OF DEVELOPMENT WORK

Misguided and insufficient exploration of the ore bodies is often the reason for failure to make a mine out of a prospect or to make a mine a profitable producer over a period of years. Lack of capital frequently prevents owners or operators of small mines from extending development work unless they can do so out of profits from the ore. To make a salable product may require a milling plant, the expenditure for which, based on the ore exposed, may or may not be justifiable. However, the desire to produce, not only by the operator but by those who have financed the initial development work on the prospect, spurs them to put up more capital for unwarranted expenditures on plants in the hope of quick return rather than to use this capital for essential development work. No expenditure on a treatment plant is justifiable until a sufficient tonnage of ore is developed to return the capital expenditure out of profits from the ore reserves. There are also many cases of failure where the tonnage of ore developed is ample, but the owner has wasted his capital on machinery or equipment purchased without adequate knowledge of requirement .

The owner of a prospect should realize that an examining engineer is particularly interested in the tonnage of ore exposed and the prospective profits to be derived from this ore. He therefore should concentrate upon exposing and blocking out ore in the most promising portion of the deposit and should extend exploration to find the continuation of this deposit or additional deposits. An ore deposit may have merit, even though only a small tonnage is exposed. Although the owner may have faith in what future development will show

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a competent examining engineer knows the risks of making assumptions, and rather than take such risks he will turn down the undeveloped prospect. Of the prospects examined by engineers it is estimated that only about 1 percent are reported upon favorably, the reason frequently being the lack of tonnage developed or unreasonable price or terms rather than low assay values.

Methods of Development

The topography of the surface and the type of the ore deposit are usually the deciding factors in planning the development of a mineral prospect.

To determine the most advantageous way to develop an ore body one should have good topographic maps of the surface, and on this the trenches, tunnels, drifts, and shafts along the ore deposits should be indicated. Where underground development work has been extensive a plan and vertical sections of the workings are essential guides in planning further work. The position of the ore body, as well as faults, dikes, and other geologic features, should be indicated on these mine plans and sections.

Surface Explorations

Surface exploration of any ore deposit should be carried on as extensively as possible, because this is usually the cheapest way to get information. A vein or other type of ore body should be located by cross-trenching at intervals and then exposed by stripping along its strike, if possible. Where the overburden is not too deep for such work a series of trenches usually is dug at regular intervals, at right angles to the strike. The distance between trenches is determined by the type of ore body and the depth of the soil; trenches should be close enough to determine the average width of the ore body and to avoid missing ore shoots and to permit proper sampling of the ore. Trenches over ore shoots are spaced more closely than over barren areas. Where good ore is found test pits are made to permit sampling well below the surface. Usually a vein or ore body will show in a general way the same variations in size and values along the surface as will occur in depth, although there are many exceptions.

Underground development in flat areas requires vertical or inclined shafts, from which drifts are extended along the vein or ore body, while in mountainous areas development often is carried on by a series of tunnels at different levels. The size and number of the shafts or tunnels will depend upon the daily tonnage to be extracted. Where large tonnages are to be mined provision should be made for underground storage bins and loading pockets.

Tunnels, Drifts, and Crosscuts

In a mountainous country it usually is possible to open up a vein or ore body by a drift or tunnel along the vein or by a crosscut to intersect the vein or ore body and then by drifts to develop it along its strike. The advantages of developing an ore deposit from a tunnel or adit compared to shaft-sinking are obvious. A tunnel is the cheapest method; as the workings are self-drained, no machinery is required for hoisting, haulage costs are lower than those for hoisting over the same distance, and the cost of tunneling or drifting is usually about one third that for sinking a shaft.

Shafts

Veins or other types of deposits coming to the surface may be developed by: (1) Inclined shafts following the ore body as nearly as possible along its dip either in the ore

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body or in the footwall, (2) vertical shafts adjacent to the ore body with crosscuts to the deposit, (3) a combination of vertical and inclined shafts or of a tunnel and a shaft.

The advantages of an inclined shaft are that it is kept in or close to the ore, thus avoiding crosscuts and permitting development of the vein by drifts in the ore in two directions, while the ore taken out may pay part of the development expense.

The advantages of the vertical shaft are: (1) Hoisting is faster, there is less wear on the hoisting rope, safety devices may be applied more efficiently, no pillars of ore are required for protection, except in passing through veins or deposits, and water can be bailed or pumped out more easily.

Shaft sinking is the most costly form of development work, but in some instances is the only type possible. In the development of vein deposits inclined shafts are sunk, usually following the vein or in the footwall of the vein, and are to be recommended for new developments. The inconvenience of hoisting in an inclined shaft usually is not serious enough to justify sinking a vertical shaft in country rock. The cost of a prospect shaft ranges from $7 to $60 per foot, depending on size, depth, and rock. Numerous examples, with detailed costs and speed of sinking, are given in Bulletin 357, Shaft-Sinking Practices and Costs, by E. D. Gardner and J. F. Johnson; Information Circular 6800, Mining and Milling Practices at Small Gold Mines, by E. D. Gardner and C. H. Johnson; Bulletin 381, Lead and Zinc Mining and Milling in the United States, Current Practices and Costs, Chas. F. Jackson, John B. Knaebel, and C. A. Wright; and Bulletin 363, Gold Mining and Milling in the United States and Canada, by C. F. Jackson and J. B. Knaebel.

Mine Levels

Whatever the method of entry into an ore body, mine levels or drifts, as well as crosscuts, are necessary to develop the vein or ore deposit laterally. Starting from the shaft the intervals between these mine levels usually range from 100 to 200 feet. The question of the economic interval between mine levels is discussed at length in Information Circular 6613, Factors Governing the Selection of the Proper Level Interval in Underground Mines, by William O. Vanderburg.

Drifts are extended at these level intervals along the ore body, which is prepared for stoping by raises and chutes. These raises are spaced according to the shape of the deposit to permit the extraction of the ore with the least amount of handling as well as purpose of ventilation. The cost of drifting and crosscutting varies from $2 to $20 a foot, the average cost being about $6.00. For raises the cost per foot may be slightly less. Direct cost of hand-drilling is about the same as with power drills, except in very hard rock. The progress, however, with an equal number of men working is only about one third as fast as with power drills.

Attention given to the position of a development drift in ore with reference to the walls of the vein or ore deposit will be of value when ore above the drift is stoped. If the vein is quite steep, the drift may be run equally well with the vein on either side, or in the middle. If the vein dips 60 degrees or less it is more convenient to have the drift in such a position that the stope floor will intersect the side of the drift high enough to install chutes for loading a car or a bucket.[21]

Usually there is no difference in the size or shape of drifts and crosscuts. Crosscuts in general require less timber than drifts, because the country rock away from the ore zone usually is less fractured and altered and is therefore stronger.

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21 Jackson, Chas. F., and Knaebel, J. B., Underground Chute Gates in Metal Mines: Inf. Circ. 6495, Bureau of Mines, 1931. 22 pp.

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Numerous examples and detailed costs of drifting and crosscutting are given in the series of papers on mining methods and costs during the last few years by the Bureau of Mines and in the Mining Engineers' Handbook, by Robert Peele.

Sampling and Exploration by Means of Hammer Drills

For underground sampling and exploration of ore deposits, light hammer drills, using unjointed bars of steel, are used widely as a means of determining the presence or the width of ore bodies 5 to 20 feet beyond the existing faces. The cuttings from such holes are collected and assayed, and the grade of the ore is calculated on the basis of the assays from these drill-hole samples. Fairly reliable results thus may be obtained at a low cost, and often parallel veins or lenses of ore have thus been discovered which otherwise would have been missed. Deep-hole drilling with heavy hammer-type machines and sectional steel frequently is used for holes up to 500 feet that are horizontal or inclined up to a 30-degree angle. The sludge is collected for the sample. In southeast Missouri, using a heavy Leyner-type machine, holes 35 to 78 feet were drilled at a contract labor cost of 16 cents per foot, according to Knaebel.[22] It is generally assumed that the "deep-hole" method is less expensive than diamond drilling, but for holes over 100 feet long the cost per foot with the new light diamond-drill outfits is not much greater than drilling deep holes. One has the advantage of speed and a core of the country rock as well as the ore which for purposes of correlation are better than sludge samples.

Diamond Drilling

The object of diamond drilling is to outline known ore bodies and to prospect outlying areas, to block out ore reserves and guide mine developments. The diamond-drill core is a representative sample of the ore and rock traversed and may be assayed to determine the metal content of the ore and studied to determine the geological relations of the rock.

Diamond-drill cores range in diameter from 1 inch to 2 inches, according to the depth of the hole, and the machines are operated by compressed air, gasoline, electric or steam power. The water required is 60 to 110 gallons per hour, of which there is about 25 percent loss, if all water returns to the collar of the drill hole and the overflow from the sludge box can be reused. A consumption of 60 to 70 barrels a day is an average for deep-drilling outfits. The drilling speed ranges from 1 foot to 8 feet an hour actual drilling time, which is 25 to 50 percent of the total time. The cost of drilling is $2.00 to $6.00 a foot, with some records below $2.00 and many instances where the costs were over $6.00.

As diamond drilling requires specialists to obtain the best results the work usually is done on contract, except at large mines with trained crews for the work.[23] [24]

Shot Drilling

Shot drills, which use steel shot in place of diamonds in core drilling, are used extensively in sampling bedded deposits from the surface. The advantages of the shot over the diamond drill are its ability to bore holes of large diameter and the low cost of the abrasives of the bit; moreover, less experience is required of operators. The average speed for a 3-1/8- to 5-inch core in average rock is 1 foot per hour. Shot drilling is limited to

22 Knaebel, John B. Sampling and Exploration by Means of Hammer Drills: Inf. Circ. 6594 Bureau of Mines, 1932, 29 pp.

23 Peele, Robert, Mining Engineers Handbook: 2d ed., John Wiley & Sons (Inc.), New York, 1927, pp. 373-400.

24 Hansen, Mayor G., Diamond Drilling at the United Verde Mine, Inf. Circ. 6708, Bureau of Mines, 1933.

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downward holes from 45 degrees to vertical. Shot drill holes may cost more per foot than diamond-drill holes due to the higher power consumption. For more specific data the reader is referred to the catalogue of the Calyx Shot Drill Co. and to pages 391 to 393 of the Mining Engineers' Handbook, by Robert Peele.

Churn Drilling

Where vertical holes from the surface are required these can be made with a churn drill. Such holes usually are 6 inches in diameter; when drilling is done in solid rock the speed is 1 to 2 feet an hour and the cost $0.50 to $6.00 per foot, with a probable average of about $2.50.[25]

SAMPLING AND TONNAGE ESTIMATION OF ORE DEPOSITS

The basis for any investment in a prospect are the average assay values of the ore and the tonnage of ore developed. The importance of getting and properly presenting such information often is not realized by the owner until he attempts to interest capital in developing his property. Bureau of Mines Bulletin 356, also Information Circular 6748, and the Mining Engineers Handbook describe in detail the standard methods of ore sampling and making tonnage estimates.[26]

The regular deposits in which the valuable minerals are distributed uniformly are the simplest type to sample by the ordinary drill or channel sampling methods and sampling becomes increasingly difficult with more erratic mineralization. In veins containing precious metals irregularly distributed there is the question of rejecting pieces of visable metal in the sample or discarding the exceptionally high sample assays in making up the averages. The size of sample to be cut and the sample interval are also important considerations and depend upon the distribution of the ore minerals in the gangue. The more uneven this distribution is, the larger the size of the sample and the smaller the interval between samples in order to obtain satisfactory results. The mineralization in some ore deposits is so erratic that only by a large tonnage mill test can the average grade of the ore be determined.

In making tonnage estimates certain assumptions have to be made regarding the continuity and grade of ore between exposed and sampled openings and extensions of ore beyond exposed ore faces. The accuracy of the estimates will depend to a large extent upon the experience, integrity and soundness of judgment of the engineer responsible for them.

Tonnage estimates are usually classified under three separate headings: "Developed ore", "Probable ore", and "Possible ore." Developed ore is usually ore, the continuity and grade of which have been proved on four, or at least three, sides not over 150 feet apart, and allowances should be made for loss in mining and dilution with waste. Probable ore includes the portions of the orebody that are exposed on two sides plus small additional portions beyond these sides, but here, too, the engineer must limit himself to certain conservative distances for extensions of ore beyond exposed faces. In estimating possible ore more latitude may be taken in deciding the limits of the ore occurrence beyond the known faces but these limits must be based on logical geological criteria or interpretation.

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25 Peele, Robert, Mining Engineers Handbook: 2d ed., John Wiley & Sons (Inc.), New York, 1927, pp. 356-366.

26 Jackson, Chas. F. and Knaebel, J. B., Sampling and Estimation of Ore Deposits: Bull. 356, Bureau of Mines, 1932 155 pp.

Wright, Charles Will, Essentials for a Preliminary Report on a Small Lode-Gold Mine or Prospect, with Notes on Sampling: Inf. Circ. 6748, Bureau of Mines, 1933. 12 pp.

Peele, Robert, Mining Engineers Handbook: 2d ed., John Wiley & Sons (Inc.), New York, 1927, pp. 1845-1964.

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MINING METHODS AND COSTS

The features that influence the choice of mining methods are size, shape, and dip of the ore body, continuity in depth and length, regularity of ore boundaries, strength of ore and wall rocks, grade of ore and distribution of metal contents, structural irregularities, faults, slips, joints, and fracture zones. In the usual type of vein deposit where the wall rock as well as the ore is fairly solid the open stope or cut-and-fill methods are in most common use. If the walls are not strong enough, then stulls or square-sets are used, often followed by filling. All these methods permit sorting of ore in the stopes and selective mining. The shrinkage and caving and sublevel-stoping methods are applied to large, low-grade deposits for large-scale or wholesale mining.

Large production requires large ore bodies and large initial investment in development and preparations. Where such operations are contemplated the problems of safety, good ventilation, and continuity of flow of ore from the stopes to the cars, taking the utmost advantage of gravity, are of prime importance for low-cost operation.

Mining conditions being the same, a narrow (2- to 3-foot) vein will cost twice as much per ton to mine as a vein 6 to 8 feet wide, but if the vein is 10 to 20 feet wide the mining cost will be only slightly less than that of a 6-foot vein.

The advantages and disadvantages of the different mining methods and comparative results at a large number of mines in the consumption of man-hours, explosives, power, and supplies per ton mined, are given in Information Circular 6503,[27] by the author.

The following tables are taken from this paper:

Average results for different mining methods; 1929 figures

Mining method	Man-hours per ton, all underground labor	Tons per man-shift, all underground labor	Explosive used per ton, pounds	Power, kw. hr. per ton	Total underground cost per ton
Square-set	5.15	1.553	1.363	34.9	$4.825
Average of	61 mines	61 mines	10 mines	19 mines	11 mines
Cut-and-fill	4.34	1.843	.660	10.045	$3.076
Average of	21 mines	21 mines	5 mines	4 mines	5 mines
Shrinkage	1.33	6.015	1.656	15.33	$2.682
Average of	37 mines	37 mines	18 mines	16 mines	16 mines
Open-stope	1.17	6.837	.844	8.90	$1.250
Average of	170 mines	170 mines	22 mines	17 mines	19 mines
Sublevel caving	.95	8.421	.605	13.00	$1.438
Average of	17 mines	17 mines	4 mines	2 mines	2 mines
Top slicing	.932	8.584	.520	7.252	$1.208
Average of	37 mines	37 mines	13 mines	12 mines	3 mines
Caving	.628	12.739	.244	3.0	.516
Average of	7 mines	7 mines	3 mines	3 mines	4 mines
		Surface			
Opencut	.324	24.691	.308	2.71	.309
Average of	55 mines	55 mines	3 mines	3 mines	3 mines

27 Wright, Charles Will. Mining Methods and Costs at Metal Mines of the United States: Inf. Circ. 6503 Bureau of Mines, 1931, 39 pp.

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The following table shows roughly the relative consumption of labor, explosives, and power, according to the metal mined; the number of mines from which the data were obtained is indicated in each case. With data from more mines and for a period of years, these averages would be more representative.

Labor, explosives, and power consumption in metal mines

Metal	Man-hours per ton mined	Man-hours per unit of product	Explosives, pound per ton mined	Power kw. hr. per ton
Iron underground	1.14 (94 mines)	2.35 (tons)(94 mines)	0.548 (30 mines)	8.38 (30 mines)
Iron opencut	.39 (48 mines)	.82 (tons)(48 mines)		
Copper underground	1.63 (63 mines)	.046 (lb.)(63 mines)	.439 (10 mines)	7.64 (10 mines)
Copper opencut	.29 (7 mines)	.014 (lb.)(7 mines)	.308 (3 mines)	2.71 (3 mines)
Lead and zinc	2.01 (161 mines)	.022(lb.)(161 mines)	.920 (15 mines)	17.65 (15 mines)
Gold	1.27 (31 mines)	6.41 (oz.)(31 mines)	.844 (8 mines)	9.72 (8 mines)

UNDERGROUND MINING PROBLEMS

Underground problems include drilling and blasting practice, underground support, mechanical loading, mine transportation, ventilation, drainage, and safety. The following are some of the Bureau of Mines publications on these subjects that may interest mine operators.

Bull. 306 Crane, W. R., Mining Methods and Practice in the Michigan Copper Mines: 1929, 192 pp.

Bull. 311 Gardner, E. D., Drilling and Blasting in Metal-Mine Drifts and Crosscuts: 1929, 170 pp.

Bull. 330 McElroy, G. E., Ventilation of the Large Copper Mines of Arizona: 1930, 145 pp.

Manuscript Report 1 Jackson, Chas. F., Underground Scraping Practice in Metal Mines: 1934.

I.C. 6086 McElroy, G. E., Why, When, and How to Make a Ventilation Survey of Metal Mines: 1928, 12 pp.

I.C. 6326 Jackson, Chas. F., Some Notes on Underground Transportation: 1931, 40 pp.

I.C. 6382 McElroy, G. E., Mine Ventilation in the Coeur d'Alene District, Idaho: 1931, 37 pp.

I.C. 6495 Jackson, C. F. and Knaebel, J. B., Underground Chute Gates in Metal Mines: 1931, 22 pp.

I.C. 6501 Crane, W. R., Essential Factors Influencing Subsidence and Ground Movement: 1931, 14 pp.

I.C. 6651 Crane, W. R., Abstracts of Recent Articles on Mine Support: 1932, 23 pp.

Initial Mine Plants

The machinery required to do the development work will depend upon the development plan and capital available. Where capital is limited many ingenious, inexpensive devices are used to operate compressors, hoists, pumps, and haulage equipment. It is usually possible to buy second-hand machinery, such as oil- or gasoline-driven air compressors, rock drills, hoists, pumps, mine cars, and track and electrical dynamos and motors at about half the cost of new machinery. The question of transporting machinery to a prospect must also be considered, and the size and weight of individual pieces should conform to the available means of transport.

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Foundations and housing are also to be added to the cost estimates for the plant, and good construction is important for the plant. Besides the housing for the mechanical equipment, quarters for workmen, a change house, boarding house, and warehouse, a carpenter and machine shop and assay office may be necessary as work progresses. The question of a year-round water supply for mining, milling, and domestic purposes is important.

In making estimates for the cost of a mine plant, one should refer to Peele's Handbook of Mining and to catalogs of manufacturers of mining machinery. The following papers, issued by the Bureau of Mines, on costs of equipping mines also contain specific information on individual operations as well as valuable suggestions for those contemplating new mine developments and plant installations:

(1) I.C. 6591 Reigart, John R., The Cost of Developing to the Operating Stage and Equipping a Small or Medium-Sized Mine in the Tri-State Lead and Zinc District: 1932, 18 pp.
(2) I.C. 6601 Sweet, J. R., Mining Methods and Costs at the Mt. Hope Mine of the Warren Foundry and Pipe Corporation, Mt. Hope, N.J.: 1932, 31 pp.
(3) I.C. 6674 Howes, G. A., and Jackson, Chas. F., Shaft-Sinking Methods and Costs, and Cost of Plant and Equipment at the Macassa Mine, Kirkland Lake, Ontario: 1932, 10 pp.
(4) I.C. 6681 Keast, A. J., and Jackson, Chas. F., Method and Cost of Exploring, Equipping for Development, and Developing the Central Patricia Group of Claims, Northern Ontario: 1933, 13 pp.
(5) I.C. 6693 Jackson, Chas. F., Some Notes on Methods and Costs of Equipping and Developing Prospects: 1933, 24 pp.
(6) I.C. 6707 Emens, W. H., and Jackson, Chas. F., Methods and Costs of Developing and Equipping the Ashley Gold Mine, Matachewan Gold District, Ontario: 1933, 28 pp.
(7) I.C. 6730 Sweeney, E. L., Design, Equipment, and Construction Costs of the Davis-Dunkirk Concentrator, Prescott, Ariz.: 1933, 5 pp.

IMPORTANCE OF MILL TESTS

The method of treatment for the ore must be known before a mine can be valued, as its net value depends upon the percentage of metal that can be recovered economically and the cost of recovery. Where concentrates are sold to a smelter not only will there be further metal losses, but deductions will be made for deleterious or undesirable elements, besides the smelting charges. It is important to know what these deductions and charges will be.

For properties that have been in operation, these factors are known, but for newly developed properties it usually is necessary to have a large-scale mill test preceded by laboratory tests to determine the method to be used for the large test. Such tests require 1 to 100 tons of average-grade ore and the cost at commercial testing plants will range from $500 to $5,000. If ore of similar character is being treated within the district the mill results from these plants should be obtained and their flow sheets studied.

Trouble has been experienced with many small properties due to faulty design and construction of milling plants based upon inadequate and inconclusive tests for determining the best flow sheet. In other instances, 100- to 200-ton mills have been erected where a 25-ton mill might have brought the prospect into production. The matter of getting the right advice is highly important, and the time one needs good advice is before starting to build a mill. The United States Bureau of Mines and the State mining bureaus and colleges are sources for information on methods of ore treatment. The textbook by Arthur F. Taggart, Ore Dressing, is another good source, and valuable information may be obtained in Robert Peele's Mining Engineers' Handbook.

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COST OF MILLING PLANTS

The cost of a mill will vary according to the nature of the ore and the method of treatment required. A flotation or amalgamation mill will cost $500 to $800, multiplied by the number of tons the mill will treat in 24 hours. Where well-constructed buildings are necessary in northern districts the cost is higher than in southern districts, where lighter construction suffices. The total cost of mills for complex ores, where two or more methods of ore treatment are combined in one plant, and for an all-slime cyaniding plant will be $1,000 to $1,500 per ton capacity in 24 hours.

Just what treatment is required depends upon the character of the ore to be milled, and it is often necessary to work out a flow sheet for the treatment of an ore using a combination of methods to get a high recovery. As most mill plants undergo changes in their flow sheet or system of ore treatment it is better to begin with a pilot plant of 10 to 20 tons capacity per 24 hours rather than to erect a 100- to 200-ton mill. Such procedure will give more time to iron out difficulties in the milling problems and to develop the mine. It may be found that a mill of only 50 tons per day capacity is large enough instead of a previously contemplated plant for 200 tons. There are many failures on record where capital has been spent on large-capacity mills for small-capacity mines, whereas the mine might have been successful with a small mill. In some instances the reason for this is the urgent demand of the investors or shareholders for profits before the mine is ready for production on a profitable basis.

MILLING COSTS

Milling costs range from 25 cents to as high as $10 per ton, depending upon the capacity of the mill, the methods of treatment used, and the ability of the mine to keep the mill running at full capacity. Shut-downs due to lack of ore or to mechanical troubles all increase the costs, and these are more serious for a mill with large capital investment than for a small one. Overhead expenses, such as administration, amortization, taxes, insurance, and interest all run 24 hours a day, and the mill should do likewise.

Details of milling costs for the different methods of ore treatment and size of plants as well as the cost of plant construction are given in the handbooks referred to by Taggart and Peele; for individual operations reference is made to the following papers on small mill plants:

(1) I.C. 6430 Blackburn, W. H., Milling Methods and Costs at the Lead-Zinc Concentrator of the Treadwall Yukon Co., Ltd., at Tybo, Nev.: 1931, 14 pp.

(2) I.C. 6447 Vanderburg, Wm. O., Milling Methods at the Hughesville Concentrator of the St. Joseph Lead Co., Hughesville, Mont.: 1931, 15 pp.

(3) I.C. 6476 Woodworth, Selim E., Milling Methods and Costs at the Argonaut Mill, Jackson, Calif.: 1931, 12 pp.

(4) I.C. 6497 Andrus, D. E., Milling Methods and Costs at the Montana Mine Concentrator of the Eagle-Picher Lead Co., Ruby, Ariz.: 1931, 14 pp.

(5) I.C. 6508 Dixon, John, Milling Practice of the Kirkland Lake Gold Mines (Ltd.), Kirkland Lake, Ontario: 1931, 13 pp.

(6) I.C. 6541 Redington, John, Milling Methods and Costs of the Coniaurum Mines, (Ltd.), Schumacher, Ontario: 1931, 5 pp.

(7) I.C. 6730 Sweeney, E. L., Design, Equipment, and Construction Costs of the Davis-Dunkirk Concentrator, Prescott, Ariz.: 1933, 5 pp.

(8) I.C. 6739 Bean, J. J., Milling Methods at the Oxide Concentrator of the International Smelting Co., Tooele, Utah: 1934, 18 pp.

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INVESTIGATION OF PLACER MINES

E. D. Gardner, in part I of Placer Mining in the Western United States (Inf. Circ. 6786) says:

> Failure to sample and estimate properly the available yardage of placer deposits has resulted in a tremendous waste of money and effort. A large proportion of all placer operations has failed because the gold in the gravel was insufficient to repay the cost of even the most efficient mining, not to mention the return of money invested or interest thereon.
>
> Many methods of sampling are available, including the simple panning of gravel from natural exposures, drifting, test-pitting or trenching, shaft-sinking, and churn-drilling. Actual mining on a small scale often is done as a method of sampling prior to investing considerable money in development or equipment.
>
> A gravel deposit of much size seldom can be sampled directly from its natural exposures; but a few creek banks, steep-sided gulches, or old excavations such as hydraulic pits may be available, in which case certain precautions should be taken to get true samples. First, the vertical extent of gravel to include in a given sample should be determined. If hydraulicking is to be done, the whole depth of gravel ordinarily is included in one sample, except when it is planned to pipe off the barren overburden to waste, in which event it is desirable to know the depth of barren material and samples may be taken of each distinguishable stratum. If drifting is planned, only the lower, economically minable gravel need be sampled. After the location and extent of a sample cut have been decided, care must be taken to have equal quantities of gravel from all points along its length. The best way to do this is to cut a channel or groove of uniform shape and size from top to bottom of the sample distance. Enough such samples must be taken to prove the continuity of the 'pay streak.'
>
> Shaft sinking is the usual method of testing placer ground. Prospect and sampling shafts, unless intended for later use in drifting or mining and unless exceptionally deep (75 feet or more), are sunk as small as practicable. The usual section is rectangular and in most districts is commonly used to crib shafts in loose gravel. In gravel tight enough to stand safely without lagging the only timber necessary is stulls set to hold the ladder.
>
> In river flats sub-surface waters usually prevent extending a shaft to bedrock, and in such instances drive-pipe sampling is the only solution.
>
> The sampling of placer deposits by drilling, or, more precisely, drive-pipe sampling, is discussed in detail by Janin.[28] He states that the Keystone no. 3 traction machine is used generally in California. The usual casing is 6 inches inside diameter and 3/8 inch thick, in 5- to 7-foot sections. Drilling without casing is not good practice, and high values in a hole so drilled cannot be accepted. The bit and stem weigh 800 to 1,000 pounds. The cutting shoe usually is about 7 1/2 inches in outside diameter. Theoretically this dimension is the diameter of the cylinder of material excavated, hence it determines the yardage per foot of hole drilled. A sand pump is used to lift the loosened gravel or sludge from the hole, usually after each foot of drilling when in pay dirt. The casing is driven ahead of the tools except when boulders or cemented gravel prevent . The casing is recovered after finishing the hole.

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28 Janin, Charles, Gold Dredging in the United States: Bull. 127, Bureau of Mines, 1918, pp. 30-49.

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Regardless of the method used, the samples taken from each foot or several feet of drilling usually is treated in a rocker, and the concentrates are panned to recover the gold. The colors are classified by eye according to size, usually into three groups, and a record is made of the number of each. Generally the gold is then amalgamated with a small quantity of mercury, which at the completion of the hole is dissolved in nitric acid. The gold is then weighed to give the total yield of the hole. Frequently the tailings from rocking and panning are saved and reconcentrated at the completion of the hole to detect and recover gold lost during the first washing.

The value of gravel in cents per cubic yard equals weight of gold recovered in milligrams times value of gold in cents per milligram times the conversion factor 27 (cubic feet per cubic yard), divided by the depth drilled in feet times the cross-sectional area of the hole, or briefly,

$$V \text{ (cents per yard)} = \frac{\text{weight of gold (mg)} \times 0.06 \times 27}{\text{depth drilled (feet)} \times 0.3068}.$$

As an aid in determining the depth of placer deposits, geophysical prospecting methods have been applied successfully in many instances. Where the bedrock is of homogeneous or uniform magnetic permeability and where considerable magnetite is associated with valuable gold concentrations, magnetometer surveys can outline these leads quite accurately.[29] The instruments used most for this purpose are the Thompson-Thalen, Askania and Hotchkiss magnetometers, which measure slight changes in the intensity of the earth's magnetic field. Operation of these instruments is not difficult, but correct interpretation of the results requires experience.

Where uniform bedrock conditions do not exist the magnetic work must be supplemented with electrical work to obtain complementary data for use in interpreting the magnetic anomalies. The electrical work gives information on thickness of gravel and depth to bedrock, contour and outline of the underlying bedrock, and other structural features which may be of value in planning the mining operations.

It must be emphasized that no geophysical method or combination of methods is offered by reputable engineers as a means for determining the commercial value of placer-gold deposits. However, information gained by geophysical methods as to the physical features of the deposit are of great value both in subsequent testing and in developing and operating the property.

Apart from the deposit itself, the water supply is the most important factor in determining the application of hydraulicking and the scale of operation. Under any given conditions the daily yardage is roughly proportional to the quantity of water used. The quantity excavated likewise is proportional to the head used on the giants, but the higher pressure is of less value in driving and washing and of none at all in sluicing the gravel through the boxes to the dump. As the cutting and sweeping capacity of the giants usually exceeds the carrying capacity of water a stream of flowing water, known as 'by-wash', or 'bank water', is directed through the pit and into the sluices.

The preparatory or development work necessary to start hydraulicking usually is greater than that for any other form of placer mining except dredging or drift

29 Laylander, K. C., Magnetometric Surveying as an Aid in Exploring Placer Ground: Eng. and Min. Jour. vol. 121, Feb. 20, 1927, pp. 325-328.

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mining. A deposit preferably is opened at the lower end to permit gravity drainage and progressive mining of the entire deposit in an orderly fashion.

A single mine may have many miles of ditch, costing perhaps $2,500 per mile, as well as dams and reservoirs and thousands of feet of flumes, tunnels, or inverted siphons. The mechanical equipment of a hydraulic mine ordinarily consists of a few hundred to a few thousand feet of 10- to 30-inch, or larger, iron pipe, one or more monitors, and a varying number of sluice boxes; the cost of equipment ordinarily is small compared to the expenditures necessary for ditches and tail races.

Although it is obvious that the recoverable gold content of the gravel must pay a profit over operating costs, which usually range from 5 to 20 cents per yard, a surprising number of ventures in hydraulicking have failed because the promoters have not allowed for all the preparatory expenses noted above. Each yard of gravel mined must carry its share of this cost, therefore the size of the deposit is of utmost importance in considering a hydraulic mining venture.

Hydraulicking under suitable conditions is a low-cost method as it yields a larger production per man-shift than any other method except dredging. The initial investment required is less than that for dredging; hence, hydraulicking in small or medium-size deposits may be more economical even though dredging would result in a lower operating cost. When the operations are on a very large scale hydraulicking costs are lower than dredging costs on a comparable basis Very clayey or bouldery gravels should be hydraulicked as dredging usually is unsatisfactory in such ground."

To determine the profits from placer deposits of known yardage and value is a simpler and, one might say, a safer undertaking than estimating profits from vein or lode deposits. Costs depend upon the method to be used, water supply, and yardage to be treated per shift. Costs as low as 4 cents per cubic yard are being obtained in dredging and hydraulic operations and as low as 10 cents in drag-line operations, but they are often many times higher.

It is of utmost importance that those intending to finance a placer property have it examined and sampled by a competent placer-mining engineer rather than base their estimates and plans of operation on reports prepared by the owner of the property. The increased interest in gold mining has attracted many operators experienced in sand and gravel operations who may have idle equipment and inventors with "trick" gold-saving machinery who wish to test their devices. These men, inexperienced in placer mining, fully believe that all that is necessary is to find a placer deposit and get capital to start operations. They induce their friends to help finance their ventures or promote a company for public subscription. Nearly all such attempts have been unsuccessful; they have failed principally because the yield from the placer deposit was less than was anticipated and the operating costs higher than estimated.

In any placer-mining undertaking it is advisable to use only standard equipment which has been proved to be the simplest and most satisfactory.

Gardner, in the information circulars mentioned, presents a number of tables giving cost data and other information on a number of placer mines classified according to the method of operation. The reader is also referred to the reports by the State mining bureaus and to the following publications:

Janin, Charles, Gold Dredging in the United States: Bull. 127, Bureau of Mines, 1918, 226 pp.
Wilson, E. B., Hydraulic and Placer Mining: John Wiley & Sons, New York, 1918.
Wimmler, Norman L., Placer-Mining Methods and Costs in Alaska: Bull. 259. Bureau of Mines, 1927, 236 pp.

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Boericke, W. F., Prospecting and Operating Small Gold Placers: John Wiley & Sons, Inc., New York.

Gardner, E. D. and Johnson, C. H., Placer Mining in the Western States:

Part I - General Information on Shoveling and Ground Sluicing: Inf. Circ. 6786, 1934, 73 pp.

Part II - Hydraulicking, Treatment of Placer Concentrates and Marketing of Gold: Inf. Circ. 6787, 1934, 89 pp.

Part III - Dredging and Other Forms of Mechanical Handling of Gravel and Drift Mining: Inf. Circ. 6788, 1935, 81 pp.

von Bernewitz, M. W., Handbook for Prospectors: McGraw-Hill Publishing Co., Inc., New York.

IMPORTANCE OF MARKET STUDIES

As the gross profit from mining operations is the market or selling price of the product minus production and transportation costs one must consider with greatest care what the future average prices for the metal to be mined probably will be. Such an estimate not only takes into account past price averages but what future demands may be for the product under consideration and what the competitive mineral products are and their selling prices. One must also consider the other sources of supply of the product, the production costs at these sources, and their proximity to the markets.

Thus far there always has been a market for gold, and the prices of other metals are based on the relative value of gold. The last decade, however, has shown what variations may occur in metal prices, as well as in other mineral commodities. The following table shows some of these changes:

Average price, cents per pound (New York prices)

Metal	1911-20	1921-30	1931	1932	1933	1934
Copper	18.9	14.1	9.1	6.3	6.4	8.53
Lead	5.8	6.5	3.7	3.0	3.9	3.86
Zinc	8.4	6.3	3.8	3.0	4.0	4.51

The low prices during the last few years are no more the real prices of the metal than are the highest prices during the preceding years.

One may well ask what price should be taken for a metal or other mineral commodity in making estimates that may be regarded as safe. There are many publications that present the price curves for the metals, some going back for over 100 years, and by studying these price curves and taking into account what has been already mentioned a forecast of probable future prices may be made.

IMPORTANCE OF COMPETENT TECHNICAL ADVICE AND EFFICIENT MINE MANAGEMENT

During the past 2 years the Bureau has collected records of over 1,000 gold mines, old ones reopened and new ones developed by newly organized companies. A detailed study of the field notes indicates that only a small percentage of these operations by newly organized companies were successful, was due to three things: Insufficient tonnage of profitable ore, inexperienced or poor management, or inadequate financing. Quotations from Bureau of Mines engineers' field reports will illustrate this point.

W. O. Vanderburg, in a letter dated June 2, 1933, wrote as follows:

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I believe that 95 percent of the small mines visited are being operated by men who were honest. This was contrary to what I expected to find, although it must be admitted that in many cases the operators are not getting the most for the money spent. One major criticism in the small-mine field is the building of mills before sufficient ore has been developed to justify their erection. The plan followed in many instances is to build the mill first and then start looking for ore. In some cases after the mill was built the operator had no funds available for development work. Another common fault in the small gold mine field was the lack of planning in underground development. Very few of the mines had maps of any sort of the underground workings.

In a letter dated June 10, 1934, E. D. Gardner stated:

It is surprising to see the number of old gold properties that have been opened up by men from other lines of business. One day last week, I visited six mines in one locality. One was being operated by a building contractor from Kansas, another by a manufacturer from Chicago, a third by an electric furnace man from Pittsburgh, and so on. The sixth was managed by a so-called engineer. I doubt his mining ability, however, as he had five surface men servicing two men in the hole. The electric furnace man was building a furnace to smelt his concentrates which he may or may not make.

It is beyond all understanding why people who have been successful in non-engineering lines feel so confident they can operate a gold mine successfully. In some cases, if the money holds out long enough they learn enough to get by. In others there is not enough money in the world for them to become educated in mining. In practically all small gold operations, management or supervision consists of two thirds finding the ore and one third getting it out.

If the prospective mine operator would engage a competent mining engineer to advise him at the start rather than after an unsuccessful attempt to develop a mine the number of failures would be less. The question of management cannot be overemphasized, as so much depends upon the judicious expenditure of each dollar. A manager should not be picked because he will accept the job for half the salary of a more experienced man, as new mines cannot afford to pay for the mistakes of the inexperienced. The ability of a manager to get the most out of the men under him is another important qualification.

A paper by the author on Management of Labor in Successful Metal-Mine Operations (Inf. Circ. 6650), which was published by the Bureau of Mines in August 1932, presents the problem encountered in the development of efficient mine organizations and shows the methods used by certain mining companies in promoting efficiency.

A mine manager must know human nature and use tact in dealing with personnel problems, both with the staff and with the workmen. He must have the ability to devise ways and means of reducing costs and must exert influence over the entire organization so that both staff and workmen will endeavor to promote the company's interest. Above all, he must be an engineer with years of mining experience and of unquestioned integrity.

Managers of small mines, like many operators of small industrial companies, do not always recognize the value of accurate accounting control over their operations. To meet this situation, Bulletin 372, Accounting System and Office-Management Procedure for Medium-Size Metal Mines, by A. E. Keller, has recently been issued by the Bureau of Mines.

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MINE FINANCING

It is essential that any set-up for financing a mine should be submitted to and discussed with a competent lawyer who is familiar with State corporation and mining laws, taxes, and the various plans for the registration and issue of securities. Clear titles to the property to be financed are also essential, and the questions of water rights, disposal of tailings, mill sites, and railroad sidings solved where necessary before extensive developments are undertaken.

For small groups, where little capital is required, partnerships or syndicates often are formed. In these partnerships or syndicates a single member may be held responsible for the full amount of any indebtedness against the property, regardless of the amount of his interest. To eliminate this responsibility of the individual, stock companies are formed, which may issue assessible or nonassessible stock.

The advantage of a company with assessible stock is to permit mining operations to be started with a small initial capital. When more capital is required this is raised by an assessment and those who cannot or do not wish to pay the assessment may sell their stock or their stock may be debited to the amount of the assessment until sold. Another advantage is that small stockholders cannot be frozen out, as may be done when companies with nonassessible stock reorganize or liquidate.

The advantage of a company with fully paid nonassessible stock is that it is more easily sold to the public, and the owner is free from any liability. In such a company it is important to make ample provision for all capital requirements at the start, as it is only possible to acquire capital later through a loan or the sale of a new issue of stock, which cannot always be done.

Because of the numerous worthless mine promotions and dishonest mine promotors both the investor in mine stock and owner of a prospect are strongly advised to get reliable information on the companies in which stock is offered and the men who wish to promote a new company to acquire capital for the development of a prospect. There are many instances where the property owner has turned over his rights in exchange for stock certificates only to find that the money acquired through the sale of the company's stock has gone into the pockets of the promoters and not into mine developments. Both the public and property owners are protected to some extent in certain States by "blue-sky laws" and recently by the Securities Exchange Commission, but even with these safeguards the greatest caution should be exercised before an interest in a mine is purchased or sold.

Evaluating a Prospect

The prospective investor (not speculator) is interested in the answers to two questions: (1) How much net profit is there in the blocked out ore, and (2) what chance has the prospect to make a mine? The first question can be answered quite accurately after the ore deposit has been sampled carefully and production costs determined, but one cannot express in figures the chance of finding more ore. If the value of a prospect is the net profit on the ore exposed few of them will be found to be worthy of capital investment.

To make a mine, an ore body must be of sufficient size and grade to repay all investment in purchase, development work, and plants, besides all costs of production and interest on capital. If an owner has spent years on his property he often has too optimistic an opinion of its immediate value, and in presenting his prospect for sale he does not always appreciate the necessity for the investor to have a detailed report on the property, with title abstracts, maps, inventories, and (what is of greatest importance) detailed estimates of the tonnage and grade of ore developed. The prospective buyer must have all of this information and much more to be in position to judge the value of the prospect. Good prospects often are not considered, because this information is lacking. If, however, the investors are ready

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to send an engineer to make an examination they will first wish to have an option. The owner is thus obliged to place a value on the prospect. Those who will provide capital for development are becoming more willing to send engineers to examine prospects, provided the preliminary information is complete and the price reasonable; but they are not willing to pay for development of a prospect unless it has an exceptional showing. This readiness to devote the services of engineers and geologists and to risk their money in the examination and exploration of a property within a specific time limit should be a sufficient guarantee of good faith to the owner. Investors to-day also expect the owner to have enough faith in his property to be willing to accept payments out of production rather than to insist on large initial cash payments.

Requirements for Obtaining Capital

When it comes to a question of financing, the company or individual to whom the proposal is made will require the following information:

(1) Names and addresses of present as well as former owners of property.

(2) Copies of title record and description of claims or parcels as given in office of recorder.

(3) If property is held under partnership, copy of agreement, or if held under lease, copy of lease.

(4) Complete statement of any mortgages or indebtedness against the property.

(5) Copies of available reports made by engineers or geologists.

(6) Copies of available topographic and geologic maps of the district and a description of the geology of the district.

(7) A recent engineer's report on the property which should include:

(a) A description of the method used in sampling and name and address of the assayer.

(b) Detailed estimates of ore blocked out and assay results.

(c) Estimates of probable and possible ore reserves and supporting data.

(d) Detailed description of the surface and underground workings and their present condition or accessibility.

(e) Inventory of the buildings, plants, and equipment on the property.

(f) Copies of laboratory tests or mill tests of the ore if any have been made.

(g) Records of any ore shipments that may have been made, together with assays, results, and payments.

(h) Information on source, kind, and amount of water supply and nature of water rights; on power supply and cost; on timber supply and costs; on labor supply and wage scale; on housing and living conditions; on transportation facilities and costs; distance to nearest railroad; conditions of roads; and all other information that may help in an estimation of production costs.

Arrangements for Obtaining Capital

Formerly the price demanded for a prospect varied with the locality of the prospect and the mental attitude or financial standing of the owners. Some property owners were modest

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and demanded only a nominal sum in cash, while others felt they should have the full value of ore blocked out or even more in cash. Cash sales often were made regardless of value during boom periods, and some purchasers succeeded in realizing a profit. Today owners find it difficult to get even a small cash payment for their property on which they have invested their small fortunes. Investors usually are unwilling to put up cash except for the development work and insist that owners accept a share of eventual returns from mine production for their property.

In the light of the uncertainties inherent in mining, probably the method of financing which is fairest to owners and investors alike is the leasing system, in which the investors agree to furnish funds to develop the property and to pay an agreed royalty on each ton of ore obtained. The lease may be written with or without an option to purchase at a stated price at the end of the leasing period. Such an arrangement indicates that an owner has enough faith in the value of his prospect to be willing to share the risk with the investor. However, in many cases owners have sunk all their capital in prospects and must make a quick sale for cash on which to live. In other words, they have already gambled and feel it only fair that the investors should also gamble to carry on. In such case, an initial cash payment equal to the amount expended by the owners may be justified. On the other hand, the owners may know nothing of mining but feel that their prospects have market value,s because they have been shown to contain ore. They may have had numerous offers to lease but remain skeptical that the lessees intend to do their utmost to make the property productive. They may feel that the lessees wish merely to tie the property up for such time as will enable them to dispose of it to a third party. For these reasons owners often make unreasonable demands for an immediate sale involving an initial cash payment to be followed by regular bonded installments. It is for this reason that many promising prospects lie idle. If owners were willing and able to cooperate with legitimate investors in permitting the latter to give the prospect a fair trial, their chance of remunerative returns would be enhanced.

Information Circular 6774, Leasing System as Applied to Metal Mines, by W. O. Vanderburg, published by the Bureau of Mines in April 1934, gives a clear presentation of the leasing system. In it the bond and lease and straight lease are discussed, the advantages and disadvantages to both the lessor and lessee are presented, the terms or elements for drawing up a lease are given, and the amount of royalties to be paid for various conditions are suggested.

In the leasing system the royalty represents the division of the profit on the ore produced. It is to the advantage of both parties to the contract to make an equitable adjustment of royalty payments. High royalties put a premium on gouging for higher-grade ores and decrease the lessees' incentive to do exploration work. Leasing contracts usually stipulate certain agreements which insure a minimum amount of work or plant installation to make the property productive. By leasing, property owners deal more fairly with lessees than by demanding cash payments, as the risk on investment is minimized. In a straight lease, paying royalty alone, money that would otherwise go to making payments in the face of uncertain conditions may be used for mining purposes.

Mine owners or lessors should stipulate a time limit, granting the privilege of an extension if terms agreed upon are fulfilled; if not, the lease becomes null and void.

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